Small Business Innovation Research/Small Business Tech Transfer

Prediction of Plume Induced Rock Fracture for Landers, Phase I

Completed Technology Project (2018 - 2019)

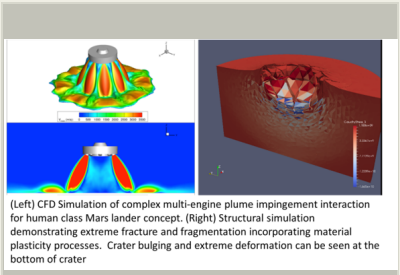
Project Introduction

The landing surface damage and liberation of debris particles caused by rocket plume impingement flow during spacecraft propulsive landing on unprepared surfaces of Moon, Mars, and other celestial bodies poses a high risk for robotic and human exploration activities. Simply determining whether the plume induced loads exceed the bedrock bearing capacity threshold is not sufficient. An integrated multi-physics simulation tool is required to capture and quantify the onset, progression and ultimate extent of the bedrock fracture processes and identify the dangers of the resulting debris transport and landing surface destruction. No such simulation capability exists to date. CFDRC has teamed with the Los Alamos National Laboratory (LANL) to propose the development of such a simulation tool that combines state-of-the-art computational fluid dynamics software for plume flowfield with a dynamic fracture mechanics structural analysis software of the rock material under plume impingement loads. The Phase I will focus on demonstrating feasibility of the proposed approach with a TRL of 2 to 3. In Phase II the models will be extended and validated to provide an accurate numerical approach for simulating plume induced rock fracture, debris transport and analysis tool, increasing the TRL by end of Phase II from 3 to 5.

Anticipated Benefits

The proposed development will offer NASA currently non-existing simulations capabilities for propulsion integration effects assessment earlier during EDL&A concept development and systems integration trade-offs. The tools will enable definition of landing pad strength and maintenance/repair infrastructure required for sustainable outpost operation scenarios. Robotic exploration scenarios frequently involve site hopping of probes with repeated take-off and landing damage potential.

Potential non-NASA applications include: a) Propulsive landing plume-surface interaction effects and debris damage assessment for commercial lander developers such as SpaceX's planned Big Falcon Spaceship for Mars exploration and others planned by entities such as Blue Origin, b) Damage prediction and resulting debris predictions for military aircraft vertical take-off and landing, and c) Damage assessment and debris predictions for future military and commercial autonomous drones operations.



(Left) CFD Simulation of complex multi-engine plume impingement interaction for human class Mars lander concept. (Right) Structural simulation demonstrating extreme fracture and fragmentation incorporating material plasticity processes. Crater bulging and extreme deformation can be seen at the bottom of crater

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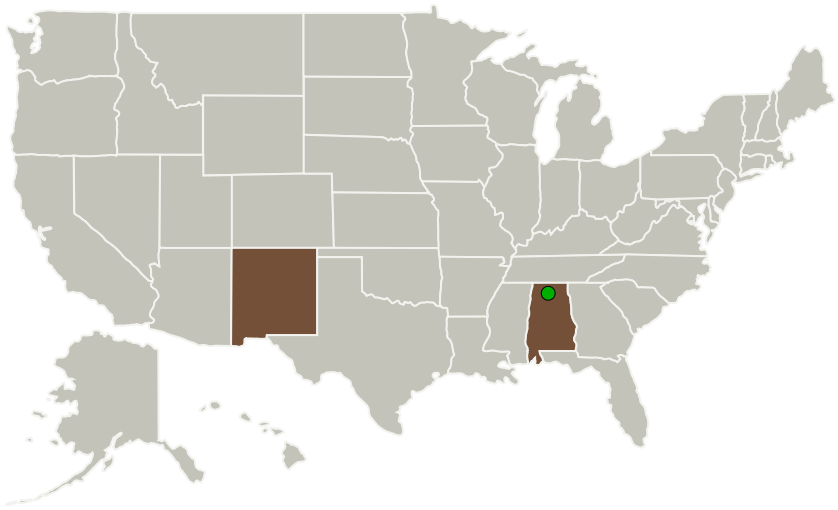
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
CFD Research Corporation	Lead Organization	Industry	Huntsville, Alabama
Los Alamos National Laboratory(LANL)	Supporting Organization	R&D Center	Los Alamos, New Mexico
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations	
Alabama	New Mexico

Project Transitions

August 2018: Project Start

August 2019: Closed out

Closeout Documentation:

- Final Summary Chart*(https://techport.nasa.gov/file/137884)*

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

CFD Research Corporation

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

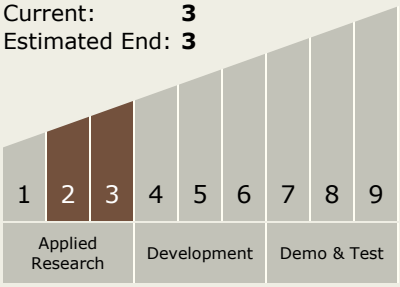
Carlos Torrez

Principal Investigator:

Ranjan Mehta

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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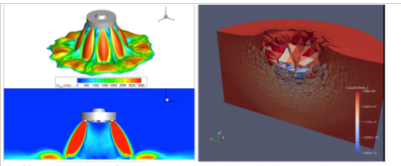
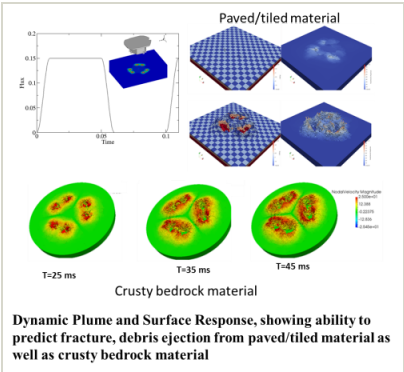
Images



Briefing Chart Image
Prediction of Plume Induced Rock Fracture for Landers, Phase I
(https://techport.nasa.gov/image/128067)



Final Summary Chart Image
Prediction of Plume Induced Rock Fracture for Landers, Phase I
(https://techport.nasa.gov/image/133494)

Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - TX09.4 Vehicle Systems
    - TX09.4.5 Modeling and Simulation for EDL

Target Destinations

The Moon, Mars, Others Inside the Solar System